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(54) **Fuel cell voltage generator**

(57) A voltage generator includes a fuel cell 1, a d.c. converter 2 and a storage battery 3. The input terminals of the converter 2 are connected to the fuel cell terminals, and the output terminals of the converter are coupled in parallel with those of the battery 3 to the voltage generator output terminals. A control means 5b of the converter 2 controls the maximum value of the current through the converter 2, according to the voltage measured at the terminals of the fuel cell 1, in order to keep this voltage in the vicinity of a preset reference value. Normally, the fuel cell supplies all of the current required by a load 4, with the battery 3 acting as a buffer. The fuel cell 1 is disconnected if its voltage remains below a minimum value, or if the voltage of battery 3 is too high or too low.

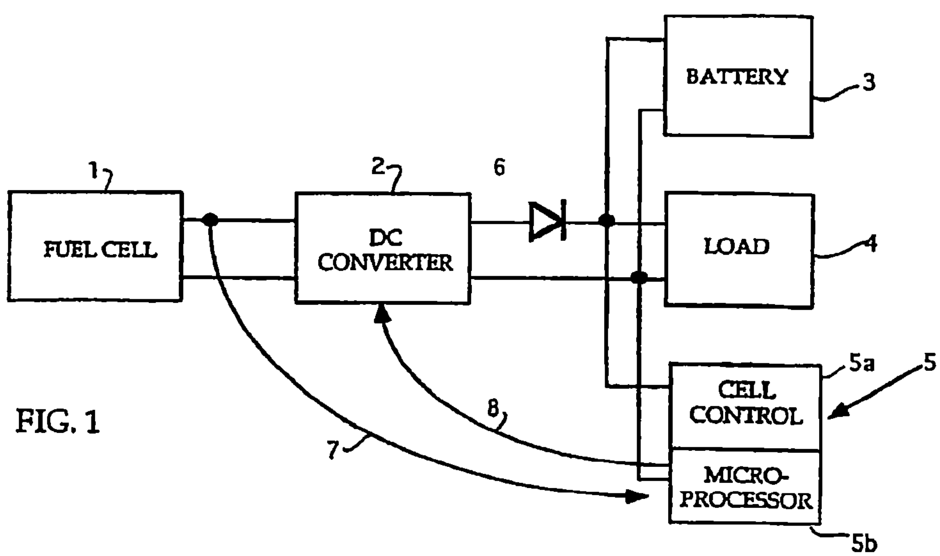

FIG. 1

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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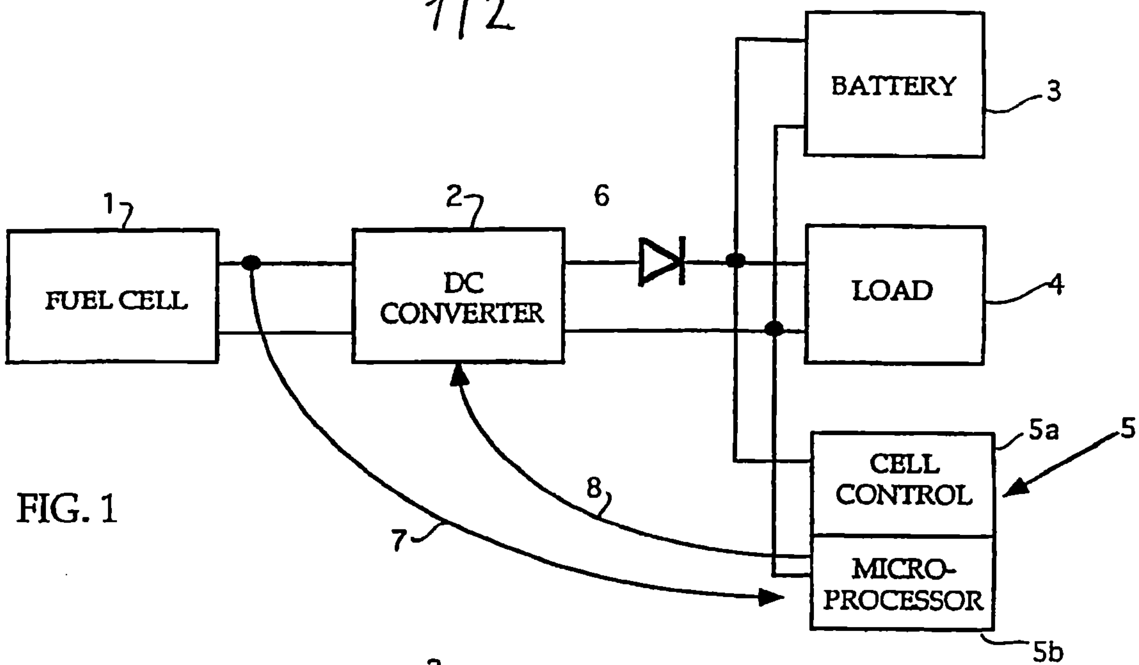

FIG. 1

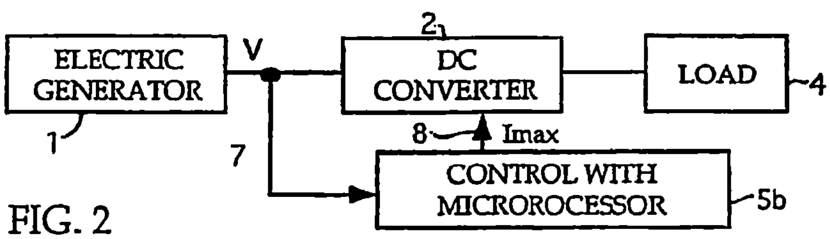

FIG. 2

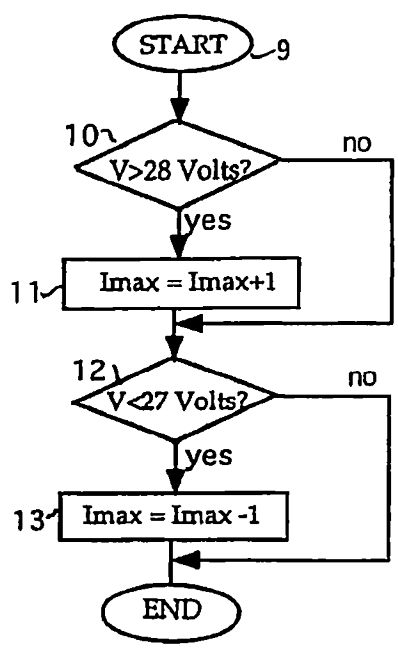

FIG. 3

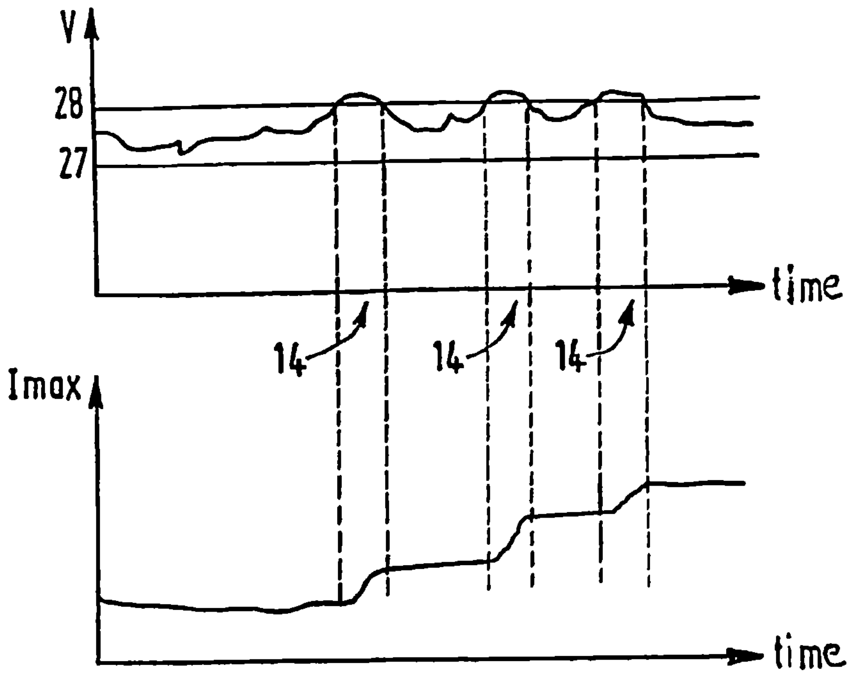

FIG. 4

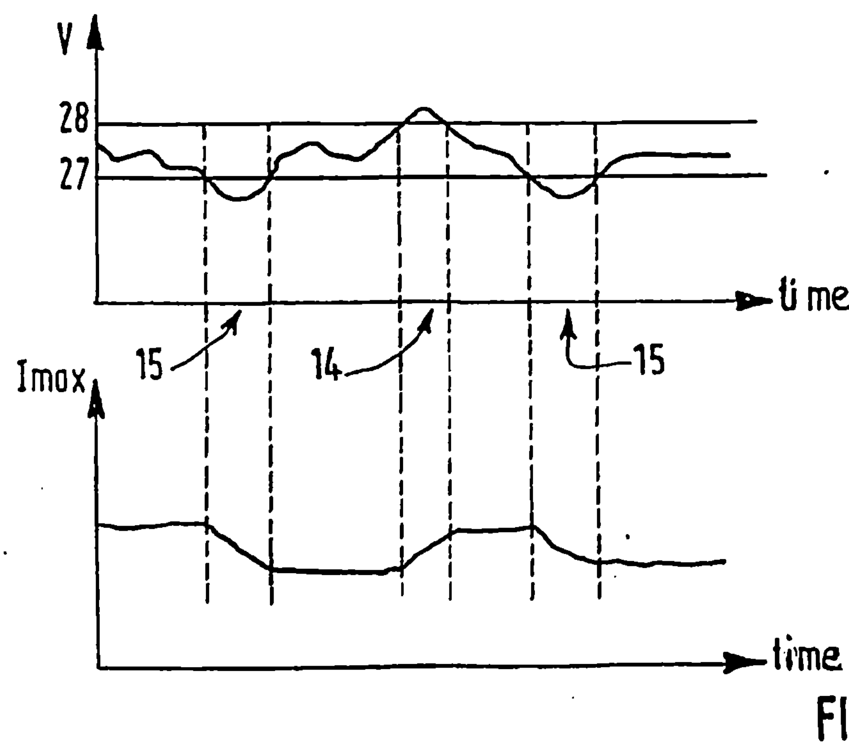

FIG. 5

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FUEL CELL VOLTAGE GENERATOR

The present invention concerns a voltage generator including a fuel cell and a storage battery assembled in parallel.

Such voltage generators, known as hybrid systems, have the advantage of constituting non polluting, silent and high efficiency energy sources, if the fuel cell produces the whole of the current available at the generator terminals.

In such hybrid systems, if the fuel cell could not cope with sudden peaks of electric energy consumption, due to the inertia of the electrochemical process taking place inside and to the limited power of the fuel cell, the associated battery acts as a buffer by supplying the additional necessary energy when needed and by storing the excess of energy in the opposite case.

It is known that, generally, a fuel cell has to work with a certain terminal voltage, otherwise its electrodes may deteriorate rapidly, which would wear out the fuel cell.

We already know hybrid systems in which a d.c. converter is placed between the fuel cell and the storage battery in order to adjust the voltage produced at the said fuel cell to a value close to the working voltage of the battery.

But these devices do not allow to prevent a lowering of the terminal voltage of the said fuel cell and they do not allow either to force at any moment the working of the fuel cell to a maximum capacity, with a storage of the excess of energy in the battery.

But these devices do not make provision for a reduction of the terminal voltage of the fuel cell or for momentary or rapid increase in the operation of the fuel cell substantially to its maximum capacity when excess energy can be stored in the battery.

We also know devices allowing, in a voltage generator of the hybrid system type, to cut off the fuel cell when current load demand is too high, that is to say when the terminal voltage of the fuel cell is lower than a minimum good working value.

But such devices, operating in the all or nothing mode, do not allow to make the most of the fuel cell, since the latter does not supply continuously its maximum output of electric power.

The present invention aims at supplying a voltage generator of the hybrid system type in which the fuel cell is kept continuously in optimal working conditions, that is to say in which, regardless of the load demand, the fuel cell supplies continuously a maximum electric power, the excess being stored in a battery used as an energy buffer.

The present invention has for an object a voltage generator comprising a fuel cell, a d.c. converter and a storage battery, the input terminals of the d.c. converter being connected to the fuel cell terminals and the output terminals of the said d.c. converter being connected, in parallel with those of the battery, on the terminals of the voltage generator, characterized by the fact that it also includes control means of the d.c. converter, acting on the maximum intensity value of the current going through the said d.c. converter, according to the voltage measured at

the terminals of the fuel cell, in order to keep this voltage in the region of a preset reference value.

The voltage generator according to the invention is original in that the d.c. converter with which it is equipped, is not used for stabilizing the voltage present at its output terminals, what would correspond to a conventional usage of a converter, but for stabilizing the voltage present at its input terminals.

In practice, the reference value of the voltage at the fuel cell terminals is determined, by experiment, as being the point of the voltage/current characteristic of the fuel cell corresponding to a maximum power output in normal working conditions of the said fuel cell.

Considering the great number of parameters conditioning the working of a fuel cell, it is, in practice, very difficult to determine instantly the power available at the terminals of the said fuel cell.

In these conditions, the value of the maximum intensity of the current going through the converter cannot be known beforehand, that is why the control means of the converter according to the invention work in an action/reaction loop by measuring the voltage at the fuel cell terminals and by adjusting the value of the maximum intensity so that the voltage measured at the fuel cell terminals corresponds to the preset reference voltage.

Advantageously, the voltage generator according to the invention is also provided with means for the disconnection of the fuel cell, which start acting in case the voltage at the fuel cell terminals stays below the reference value, in spite of the action of the control means of the converter.

In order to get a better understanding of the invention there will now be described one embodiment of a voltage generator according to the invention, given as a non restrictive example, with reference to the accompanying drawings in which:

Figure 1 is a schematic view of the different components of a voltage generator according to the invention,

Figure 2 is a synoptic diagram showing the action/reaction loop control made, according to the invention, at the fuel cell terminals,

Figure 3 is a simplified flow diagram of the microprocessor control on the d.c. converter,

Figure 4 shows the variations of electrical parameters of the generator according to the invention during a transitory phase of temperature raise, and

Figure 5 shows the variations of electrical parameters of the generator according to the invention, during a phase of variation of the current load.

In Figure 1, the output terminals of a fuel cell 1 are electrically connected to the input terminals of a d.c. converter 2.

The output terminals of the said converter 2 are coupled together with those of a rechargeable battery 3, to the terminals of a current load 4 which can be constituted, for instance, by an electric motor.

A control block 5 is also connected in parallel to the terminals of load 4.

The control block 5 is divided in two parts, a first part 5a, grouping all the means necessary to the working control of the fuel cell, that is to say its hydrogen supply, its temperature control and so on ... and the part 5b comprising the control means of the converter according to the invention, namely a microprocessor.

The working principle of the generator according to the invention is now going to be described.

At the start of operation, the battery 3 supplies at the same time the load 4 and the control means of the cell 5a, the latter being started by the said control means.

At this moment, the fuel cell 1 is not yet in action; it first has to heat up before supplying electric energy that can be used by the load 4.

As the fuel cell begins to generate enough electric power, it replaces progressively power supplied by the battery 3 so as to become the only energy source of the generator. It then also supplies the control block 5.

If the load 4 requires an electric power lower than that available at the fuel cell 1 terminals, the excess electric energy is supplied to the battery to recharge it.

In the opposite case, the battery 3 supplies power to the load 4 to compensate for the electric power lacking at the fuel cell terminals.

A semiconductor diode 6, coupled between the d.c. converter 2 and the battery 3, prevents reverse current in the fuel cell 1.

According to the invention, the voltage at the fuel cell 1 terminals is stabilized around a preset reference value, by experiment, at a value corresponding to an optimal working of the said fuel cell.

Figure 2 is a synoptic diagram showing the control in action/reaction loop made by the microprocessor on the fuel cell.

This control applies more generally to all electric generators of which the output voltage has to be stabilized.

The microprocessor 5b measures the voltage V at the electric generator terminals, as indicated by the arrows 7 on Figures 1 and 2.

The microprocessor 5b then executes the simplified flow diagram illustrated on Figure 3.

Beginning with the starting step 9, the microprocessor 5b compares in 10 the voltage value V with an upper limiting value fixed by experiment at 28 volts.

If the voltage V at the electric generator terminals is above this upper limiting value, the microprocessor triggers in 11 the incrementation of the maximum value Imax of the current going through the d.c. converter.

This rise of the Imax increases the electric power demand at the generator terminals and leads to a decrease of the voltage V.

In the opposite case, that is if the voltage V is not higher than the upper limiting value, the microprocessor 5b compares in 12, the voltage value V with a lower limiting value which is here of 27 volts.

Thus, if the voltage V is lower than 27 volts, the microprocessor 5b provokes in 13 a decrease of the Imax value of the maximum current going through the converter.

Contrary to the previous case, this Imax variation leads to an increase of the voltage V at the terminals of the electric generator.

The microprocessor 5b performs this control periodically, for instance every 10 ms.

The Figures 4 and 5 illustrate the variations of the voltage V at the fuel cell terminals and of the Imax maximum value of the current going through the converter during the working of the generator according to the invention.

The Figure 4 corresponds to the rising temperature phase of the fuel cell, when the generator starts working.

The time scales of the voltage and current curves are identical.

One can clearly see on this Figure 4 that the voltage V is kept substantially within the lower and upper limiting values which are here respectively of 27 and 28 volts.

These voltage controls are realized by changing the Imax value. Indeed, during the three periods of time shown by the reference number 14, the voltage V exceeds the upper limit of 28 volts. In reaction, the Imax value is incremented until the voltage V returns to a value below 28 volts.

The Figure 5 corresponds to the standard working of the generator according to the invention, during variations of the current demand of the load 4. During a phase 14 in which the voltage V goes above 28 volts owing to a decrease of the load 4, the Imax value is incremented until the voltage V goes down below 28 volts.

Inversely, as the load at 4 increases in phases 15 during which the voltage V is below the lower limiting value of 27 volts.

In this case, the Imax value is decremented until the voltage V reaches a value higher than 27 volts.

It is understandable that the generator according to the invention allows to make the most of the fuel cell which then works permanently under optimal conditions.

However some boundary situations have to be taken over by the control block 5, such as situations which correspond to a malfunction of the generator or to deterioration risks of the fuel cell.

Generally, the control block 5 acts for:

- disconnecting the fuel cell in case the voltage V at the terminals of the latter stays below the minimum value required for the proper working of the said cell, in spite of the power regulation realized by the d.c. converter.

- interrupting the working of the fuel cell in case the voltage at the batteries terminals is too high or too low.

It is obvious that the realization mode that has just been described is not restrictive and may undergo any desired modification without going out of the invention frame.

Possibly, one or more voltage or additional current regulators may be used in series with the load or the battery, in order to be able to control the electric power received by these apparatus according to the type of application.

CLAIMS:

1. Voltage generator comprising a fuel cell, a d.c. converter and a storage battery, the input terminals of the d.c. converter being coupled to the fuel cell terminals and the output terminals of the said d.c. converter being coupled, in parallel with those of the battery, on the voltage generator terminals, control means for the d.c. converter for controlling the intensity value of the current going through the said d.c. converter, according to the voltage measured at the terminals of the fuel cell, in order to keep said voltage in the vicinity of a preset reference value.

2. Voltage generator according to claim 1, wherein the control means for the d.c. converter act in an action/reaction loop, the value of the maximum intensity of the current going through the d.c. converter being incremented and respectively decremented when the voltage measured at the terminals of the fuel cell respectively above and below the said preset reference value.

3. Voltage generator according to claim 1 or 2, wherein the control means is arranged to increase the value of the current through said d.c. converter when said voltage is equal to or greater than a first, limiting value above said preset reference value, and to reduce the value of said current when said voltage is equal to or less than a second, limiting value below said preset reference value thereby to maintain said voltage in the vicinity of said reference value.

4. Voltage generator according to claim 1, 2 or 3, comprising means for disconnecting the fuel cell when, in

operation, said voltage is not maintained in the vicinity of said reference voltage by said control means.

5. Voltage generator substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.